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During Desert Shield/Storm, extreme weather conditions encountered in the desert environment caused equipment problems that raised questions regarding climatic design requirements. The common theme for these questions centered on whether or not the environments in MIL-STD-210C , "Climatic Information to Determine Design and Test Requirements for Military Systems and Equipment," were extreme enough. This is in sharp contrast to past criticism that MIL-STD-210C provided climatic values that were too extreme. This article addresses both of these issues in the context of what we have learned from Desert Storm.

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DESERT STORM: LESSONS LEARNED ON CLIMATIC DESIGN

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Abstract

During Desert Shield/Storm, extreme weather conditions encountered in the desert environment caused equipment problems that raised questions regarding climatic design requirements. The common theme for these questions centered on whether or not the environments in MIL-STD-210C, "Climatic Information to Determine Design and Test Requirements for Military Systems and Equipment," were extreme enough. This is in sharp contrast to past criticism that MIL-STD-210C provided climatic values that were too extreme. This article addresses both of these issues in the context of what we have learned from Desert Storm.

Preface

The concept of designing equipment to operate in and withstand the extremes of nature is essentially to establish a balance between economics and risk. Designing to the most severe possible conditions minimizes the risk of equipment failure, but it can be extremely costly. For this reason, it is human nature to downplay the risk of being exposed to extreme environments.

During its 40 year existence, MIL-STD-210 has been frequently criticized for being too extreme and being a "cost driver." This argument was often justified because of the engineering difficulty in meeting some of the climatic requirements. In the Persian Gulf, high temperatures caused a variety of problems. There were unofficial reports of temperatures well in excess of 130°F. This prompted the question: Were the climatic criteria in 210C appropriate?

How Hot Was It?

During Desert Shield/Storm, I was told of the high temperatures encountered there from engineers responsible for finding fixes to equipment problems. One engineer trying to address the heat-caused failure of voltage regulators used on generators told me of observed temperatures of 135°F(57°C). These were not, however, official temperatures observed in the shade, 1.5 m above the ground, in a ventilated shelter. Temperatures observed by a soldier on a thermometer hanging on the side of a quonset hut make for great war stories, but they do not qualify as official.

The highest officially recorded temperature on this planet was 136°F(58°C), recorded in northern Africa. The temperatures in 210C were based on the hottest part of the world which includes northern Africa eastward through the middle east to parts of India. During the hottest month of the year in this area, a temperature of 120°F(49°C) is exceeded 1% of the time, on average. In this same area, a temperature of 131°F(55°C) could be expected to occur at least once during a 60-year period.

Can we say for sure that the "reported" 135°F (57°C) temperature was erroneous? No, we can't. However, the more likely scenario that caused high temperature equipment failures was a combination of temperature and other environmental factors, especially intense solar radiation. In the case of the voltage regulator, another contributing factor could have been the heat from the generator. The main point here is that the true ambient air temperature, on which the 210C values were based, was not the appropriate design criteria for exposed equipment.

How Should Climatic Design Criteria be Developed?

MIL-STD-210C provides the following discussion on high temperature:

5.1.1 <u>High Temperature</u> Temperatures discussed in this section were observed in standard meteorological instrument shelters. They represent temperatures of the free air in the shade about 1.5 m above the ground. These high temperatures will normally be encountered only during strong sunshine and fairly light winds. The ground surface will attain temperatures 15 to 30°C higher than that of the free air, depending upon radiation, conduction, wind, and turbulence. Air layers very close to the surface will be only slightly cooler than the ground, but the decrease with height above the surface is exponential so that temperatures at 1 m will be only slightly warmer than that observed in an instrument shelter.

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The temperature attained by military equipment exposed to high temperatures will vary greatly with the physical properties of the equipment affecting heat transfer and capacity, and with the type of exposure. (Probably the worst exposure is that of equipment placed on the ground in the direct sunshine.) The heat load from a realistic diurnal air temperature and solar radiation cycle (data that can be provided from meteorological records) make up only a part of the heat transferred to the equipment. The equipment temperature will also be dependent on solar radiation reflected to it from the ground, long wave radiation from the heated ground, long wave radiation to the cold sky, scattered solar radiation from the sky and nearby clouds, the vertical temperature distribution in the free air surrounding the equipment, and total ventilation from wind and turbulence.

5.1.1.1 Highest Recorded. The world's highest recorded temperature, 58°C(136°F), occurred at El Azizia, Libya on 13 September 1922. El Azizia is located in the northern Sahara at 32°32'N, 13°01'E, elevation 112m. At least 30 years of observations are available for this station. Besides the 58°C reported, maximum temperatures of 56°C(133°F) and 53°C(127°F) for August and June have also been observed.

5.1.1.2 Frequency of Occurrence. There were insufficient hourly data to determine the distributions of high temperature versus frequency of occurrence on a global basis. Therefore, a statistical technique was used to estimate percentile temperatures for thousands of locations worldwide. Atlases containing the high temperature analyses were used to determine areas of the world with the highest 1-, 5-, and 10-percent temperatures during the worst month.

The hottest area of the world lies in the interior of northern Africa eastward to India. The hottest part of this area is the Sahara desert, which qualifies as the worst part of the world for high temperature. The 1-, 5-, and 10-percent temperatures are 49°C(120°F), 46°C(115°F), and 45°C(113°F), respectively.

Hot extremes are part of a well pronounced diurnal cycle. The daily maximum lasts only a couple of hours. However, it is accompanied by intense solar radiation that causes equipment to attain temperatures considerably higher than free-air values. Therefore, a realistic diurnal cycle including solar radiation should be considered with the hot extreme. The cycle should also include windspeed, which serves as a limiting factor to heat intensification. The moisture content is also needed since the extremely low relative humidities that can be present during the hottest situations may present special design problems.

If military materiel is to be designed to operate in a 1-percent temperature any place in the world during the warmest month of the year, then it must be designed for a diurnal cycle in which the air temperature attains a maximum of at least 49°C at a height of about 1.5 m above the ground. This cycle and associated solar radiation, relative humidity and windspeed is presented in Table I (page 72). Temperatures of 49°C will also be encountered during other months, and in hot deserts outside this area, but less frequently than 1 percent of the time.

Diurnal cycles associated with the 5 and 10 percent temperatures can be approximated by subtracting 3°C, and 4°C, respectively, from each of the hourly temperatures in Table I. Values of other elements in the cycle would not vary significantly from those associated with the 1-percent value because lower temperatures could be caused by other meteorological conditions.

5.1.1.3 Long-term Extremes. High temperatures that would be expected to occur at least once during 10-, 30, and 60 years in the hottest part of the world are 53°C(128°F), 54°C(130°F), and 55°C(131°F), respectively. These values were derived from statistical analysis of 57 years of temperature data from Death Valley, California and are considered representative of conditions in the Sahara desert. Diurnal cycles, including associated solar radiation, relative humidity, and windspeed are provided in Table II (page 73).

The point of providing the above except from 210C is to allow for a convenient reference to material that can be used to provide an example of establishing high temperature climatic requirements. As I mentioned earlier, the acceptable level of risk is the key factor in determining the extremity of the environment being designed for. If the reported temperature of 135°F was in fact the true temperature, then designing for the highest ambient air temperature ever recorded would have covered the situation. The engineer that I spoke with regarding the failing voltage regulators said that the 1% value of 120°F was used for design.

The above discussion on Frequency of Occurrence points out the importance of the cycle of solar radiation and other elements to be considered in design. It is worth noting that the 1% temperature is exceeded 1% of the time during the hottest month ON AVERAGE. Just like normal temperatures that we hear about in the daily weather forecast, actual conditions are usually above or below normal on a given day. During a particularly hot month, the 1% value may be exceeded far more often. Equipment designed for the Frequency of Occurrence values should not be expected to operate when they are exceeded, but neither should they be permanently damaged.

Long-term Extremes (see excerpt) are the appropriate climatic design values for avoiding permanent damage. The following statement is provided in the General Information section of 210C:

For some material, one-time exposure to a climatic extreme can render it permanently inoperable or dangerous (e.g., ordnance). For such materiel, long-term climatic extremes, or the record extreme, would be more appropriate for design of equipment that is not protected from the environment. (It should be noted that highest/-lowest recorded extremes depend upon the period-of-record and should not be construed as "all time" extremes). The use of these more extreme values, instead of those occurring for a percent of the time during the most severe month each year, shall be determined by the agency or department responsible for development.

The voltage regulators in our example should have been designed to a 130°F ambient environment and the associated solar radiation, etc to avoid permanent damage (based on the 30-yr. extreme).

Are the Ambient Temperatures The Design Criteria?

It is emphatically stated in 210C that the climatic values are not the design criteria. They are "intended to serve as natural environment starting points for the sequence of engineering analyses to derive environmental design criteria for material." The design criteria are actually induced environments that are created by the platform on or within which the item or materiel is located. Important environmental factors relevant to developing design criteria are discussed in the 210C excerpt under section 5.1.1.

In evaluating the voltage regulator problem, it was apparent from conversations with the investigating engineer that neither the solar radiation, nor the generator engine heat was considered for design. Also, the 1% value of 120° was the only value specified for design. The higher long-term values for irreversible damage should also have been used.

Another approach to the design problem is providing for a mitigating effect on the materiel. A cooling fan or protection from direct solar radiation are simple examples. In the Persian Gulf, aircraft cockpits were popping open due to intense solar heating. The problem was cured by covering the cockpit with a tarpaulin.

What Climatic Design Lessons Were Learned?

The war in the Persian Gulf area exposed equipment to extremely formidable environmental conditions. The meteorological values provided in MIL-STD-210 were appropriate to design equipment for this area because they represent conditions for the most extreme areas of the world during the worst month. For high temperatures, the Saudi Arabian/Iraqi deserts come very close to qualifying for this dubious honor. The conditions encountered there refute the argument that the climatic design philosophy used in 210C results in values that are too extreme.

This article discussed the failure of voltage regulators, due to a combination of conditions leading to overheating. It provided a simple example of how climatic criteria should be considered in the design process. For the most part, we learned that our military equipment worked quite well. That seems to be a pretty good indication that we're doing a lot of things right.